The amphibious rotary excavator is used to selectively create ponds and ditches in salt marshes for biological mosquito control. Broadcasting of spoil over the marsh surface as a thin slurry permits rapid re-growth of the original vegetation.

breeding sites and by providing predatory fish access to mosquito breeding areas. Marsh areas treated with OMWM can control mosquito larvae for 15 or more years. OMWM treated areas also provide new habitats for a variety of fish and wildlife species.

Impoundments are another water management technique that have been used to lessen mosquito production in marsh areas. Impoundments are created by enclosing marsh areas with an elevated, earthen dike or levee. A water control structure is often installed in this dike to allow for manipulation of the water level within the impoundment. Floodwater mosquito production can be largely reduced by permanently flooding the impounded area thus making it unsuitable egg-laying habitat for floodwater mosquito species. Mosquitoes which deposit their eggs on the water surface can be controlled by fish living within the impoundment. While new impoundments are currently not being constructed, existing impoundments are being managed to control mosquitoes and to benefit many fish and wildlife species.

Individual homeowners can assist the Mosquito Control Section by eliminating mosquito breeding sites around the home which retain rainwater (e.g., clogged rain gutters, discarded tires, abandoned containers, and neglected bird baths). Concerns regarding persistent wet areas on property should be directed to appropriate drainage agencies.

Man-made containers that hold water, such as discarded tires, create prime mosquito breeding habitat.

Checklist of Possible Mosquito Sources Around the Home:

Sources and remedies

- **Ornamental ponds -** stock with fish, remove excess emergent vegetation
- **Swimming pools** - remove water from pool cover, keep chlorinated and filtered
- **Bird baths** - change water once a week
- **Rain gutters** - keep clear of debris so that water can drain
- **Containers** - remove, cover, invert, or dump regularly

It can take less than one week for mosquitoes to complete their life cycle; therefore water must be removed or changed weekly.

Other examples of typical items around the yard that easily collect water include the following: wheel barrows, flower pots, tires, buckets, toys, boats, tarps, pet dishes, troughs, trash cans and lids, children's wading pools, and lawn ornaments.

You can protect your family and neighbors from pesky mosquitoes and potential mosquito-borne diseases by diligently monitoring these items. Container breeding species do not fly far and can be the source of mosquitoes for an entire neighborhood.

Personal Protection Measures

- Apply repellent containing DEET according to the label's directions.
- Wear long-sleeved shirts and long pants.
- Avoid being outdoors during peak mosquito activity (from dusk to dawn).
- Ensure that all window and door screens are secure and functional.

For additional information contact:

Mosquito Control Section
Delaware Division of Fish & Wildlife
89 Kings Highway
Dover, DE 19901

Telephone:
New Castle County - (302) 836-2555
Kent & Sussex Counties - (302) 422-1512

Visit our website at:

www.dnrec.state.de.us/fw/mosquito.htm

Division of Fish and Wildlife Mosquito Control Section

Mosquito Control in Delaware

The Mosquito Control Section of the Department of Natural Resources and Environmental Control's Division of Fish and Wildlife is the agency responsible for reducing mosquito populations in Delaware without adversely affecting human health or the environment. Currently the Section maintains operational offices in Newark and Milford.

The Mosquito Control Section utilizes an Integrated Pest Management program which combines chemical, biological, and physical control measures. Control of larvae is usually more effective than widespread adult control since the larvae are concentrated in smaller, well-defined aquatic habitats. Biological control of larvae is best achieved through water management projects which provide mosquito consuming fish access to mosquito breeding sites. If larval control methods are successful, the need for adult control is greatly reduced or eliminated.

Mosquito nuisance levels are monitored via public complaints, field inspections, and automated traps. Control measures are initiated when mosquito populations reach nuisance levels or mosquito-transmitted diseases are detected. Blood or tissue samples are taken from caged chickens exposed to biting mosquitoes and specific species of dead wild birds (contact Mosquito Control for the current list of accepted species) to determine the presence of viral organisms which can be transmitted to humans or animals by the bite of mosquitoes.

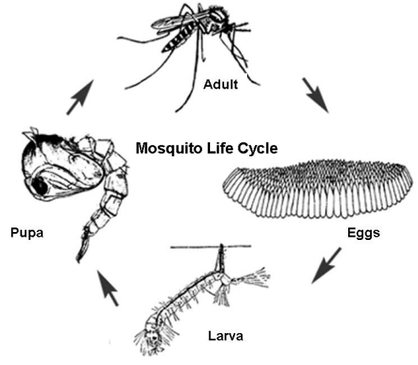
Insecticides are strategically applied using ground or aerial equipment to control adult or larval (immature) mosquitoes. All insecticides used by the Mosquito Control Section are registered by the Environmental Protection Agency (EPA) for mosquito control and applied according to EPA approved label instructions. The EPA has determined that these products can be used without posing unreasonable risks to human health, wildlife, or the environment.

The following topics are discussed in detail:

- **Mosquito Biology** - life cycle and habitats of mosquitoes
- **Mosquito Sampling Programs** - techniques used to measure mosquito abundance and the presence of mosquito transmitted diseases
- **Mosquito Control with Insecticides** - types of insecticides used to control mosquitoes
- **Biological Mosquito Control Using Water Management** - reducing larval mosquito populations using water management techniques which promote natural mosquito control

Mosquito Biology

Mosquitoes are a diverse group of insects closely related to flies, with at least 57 mosquito species occurring in Delaware. Male and female mosquitoes feed mainly on flower nectar for energy. Only female mosquitoes bite,



***Mosquito life cycle**—Clockwise from right—egg raft on water surface, larva, pupa, and adult. Some species lay their eggs on standing water, while other species lay eggs on moist mud.* (Image used with permission from Ohio State University Extension.)

drawing blood with piercing and sucking mouthparts to enable egg production. Most species are fairly specific in their biting preferences (e.g., some bite only amphibians, some only birds, while others only mammals such as horses or humans) and some will feed on a combination of animals.

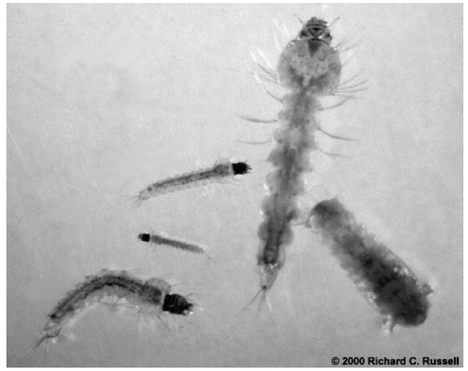
All mosquito species require water to complete their life cycles from egg to adult. All life stages except the adult are aquatic. Eggs are deposited on water or on moist soil near water. Eggs deposited on moist soil hatch when flooded by water. Mosquitoes develop through four larval stages, progress to a pupal stage (the final stage before adult emergence), and finally emerge as adults. The process from egg to adult can take as little as five days during hot weather and up to as long as a month or more in cool weather. The mosquito season in Delaware starts in March and can extend through November, with adults most abundant from April through September. Some species can produce 10 generations per year.

Mosquitoes utilize a wide variety of aquatic habitats as breeding sites, with individual species usually restricted to a specific habitat. Stagnant water isolated from mosquito predators is ideal breeding habitat. Salt and fresh water marshes, flooded woodlands, and various habitat associated with human occupation (e.g., old tires, clogged rain gutters, and blocked drainage ditches) are the principle mosquito breeding habitats in Delaware. Each habitat produces a

unique group of mosquito species.

Variations in rainfall patterns influence mosquito population levels. Mosquitoes which deposit eggs directly on water (e.g., *Culex* and *Anopheles* species) are most abundant after periods of high rainfall. Rainfall also affects quantities of floodwater species on fresh water marshes. The abundance of the saltmarsh mosquito (*Aedes sollicitans*) is dependent on both tidal flooding and rainfall patterns. Saltmarsh mosquito populations are lowest when weather or astronomical conditions prevent flooding of high marsh areas where eggs have been deposited. The greatest production occurs when rainfall or higher than normal tides flood high areas of the salt marsh after a dry period.

Some mosquito species remain close to their breeding areas after emerging as adults while others, such as the saltmarsh mosquito, can fly up to 40 miles from their larval development areas.



***Larval instars**—four larval instars (growth stages) are represented above along with the final stage, the pupa (on right).* (Image used with permission from The Department of Medical Entomology http://medent.usyd.edu.au.)

Mosquito Sampling Programs

Accurate monitoring of mosquito population levels is essential to the timely and effective control of mosquito outbreaks. Vigilant sampling of larval (immature) mosquito populations provides data which assist in timing insecticide applications to control larvae before emergence as biting adults. Information on larval densities, age, species, and percent of the area breeding mosquitoes is used in determining where and when insecticide treatment is required. Estimates of adult female mosquito abundance are made by counting the number of mosquitoes landing on Mosquito Control inspectors during one minute. Automated light traps which attract and collect adult mosquitoes are also utilized throughout the state to determine levels of adult mosquito infestation. Chemical control measures are initiated when sampling indicates high populations of adult mosquitoes known to bite humans.

In addition to measuring mosquito nuisance levels, the Mosquito Control Section also monitors for the presence of diseases which can be transmitted by mosquitoes to humans or animals. Of primary concern are Eastern Equine Encephalitis (EEE) and West Nile virus (WNV), both potentially deadly viruses which infect the brain of susceptible birds and mammals (e.g., horses and humans). Within the human population, the elderly are the most at risk. Mosquitoes contract both viruses by feeding on an infected wild bird and later transmit the virus while feeding on another animal.

A "New Jersey" style light trap for monitoring adult mosquitoes. A light to attract the mosquitoes is under the funnel and a fan near the top directs mosquitoes into a collection jar at the bottom.

EEE and WNV levels are monitored by Mosquito Control using several techniques. In June, caged chickens are distributed throughout the state and exposed to biting mosquitoes for the purpose of disease surveillance. These sentinel flocks remain in the field until early November. Weekly blood samples are collected from the chickens and analyzed for the presence of EEE and/or WNV by the Division of Public Health laboratory. Certain species of dead wild birds are also tested for WNV. Mosquito species known to transmit these viruses are sometimes analyzed as well. When Mosquito Control's monitoring programs document the presence of EEE and WNV, control measures are initiated in order to minimize the chance of human infection. Horses can be protected from both viruses with vigilant vaccination.

Canine heartworm, a disease fatal to dogs, is circulated within the dog population by biting mosquitoes. The Mosquito Control Section does not monitor heartworm levels in the mosquito population. Dog owners are encouraged to protect their pets from heartworm by administering preventative medications year-round.

Mosquito Control with Insecticides

Insecticides used for mosquito control are grouped into two categories. Larvicides are used in aquatic habitats to control immature (larval) mosquitoes. Adulticides are applied to the air to control adult mosquitoes. All insecticides used by Mosquito Control are registered by the U.S. Environmental Protection Agency and pose no unreasonable risk to human health, wildlife, or the environment when used as directed.

Larviciding is the most efficient and effective method of controlling mosquitoes since the larvae are concentrated in relatively small breeding areas. Larvicides are applied to primary mosquito breeding habitats within Delaware before the larvae emerge as adults. The primary breeding habitats found in Delaware are salt marshes, fresh water wetlands, wet woodlands, and roadside ditches. Larviciding is accomplished in small areas using hand-held or truck-mounted equipment. Larger tracts of land are treated using helicopters or airplanes. Methoprene, Bti, and temephos are currently the principle larvicides used by Mosquito Control. These products are environmentally compatible due to the rapid "breakdown" of the product.

Fixed-wing aircraft are used to apply insecticides when vast expanses of marsh, woods, or developed areas need treatment.

Control of adult mosquitoes becomes necessary if larviciding is ineffective or not accomplished due to weather. Truck-mounted "foggers" are used to apply adulticides in relatively small areas such as housing developments. Airplanes are used to apply adulticides over large areas such as towns or rural areas when necessary.

The adulticide compounds currently used in Delaware are naled and synthetic pyrethroids. These products are short-lived and must be reapplied for each adult mosquito infestation. Adulticiding is generally more costly than larviciding because adulticide applications are usually performed over larger areas.

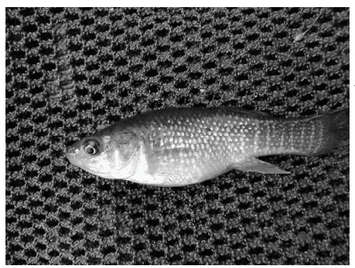
Adulticides are applied by a truck-mounted "fogger" in residential areas.

The Mosquito Control Section evaluates new mosquito control insecticides as they become available. New products must provide consistent control of mosquitoes, be environmentally compatible, non-hazardous to humans, and cost effective. If new products meet these requirements, they are considered for possible use by the Section in its battle against mosquitoes in Delaware.

Helicopters are used to apply insecticides when small or localized areas must be treated. They are also a valuable tool for checking remote suspected mosquito breeding areas.

Biological Mosquito Control Using Water Management

Biological control is a natural form of pest control. The Mosquito Control Section enhances the biological control of larval mosquitoes by installing water management systems in mosquito breeding areas. Mosquito Control uses water management systems to manipulate water levels in order to interrupt mosquito life cycles before the larvae emerge as adults. Water management systems control mosquitoes by altering mosquito breeding sites so they are unsuitable for egg and larval development and/or by providing access for larvae-consuming fish to mosquito breeding sites. Mosquito fish (*Gambusia holbrooki*) readily consume mosquito larvae and can sometimes be stocked and established in areas that have low predatory fish populations. Biological control provides more permanent mosquito control than chemical insecticides, resulting in a substantial reduction in insecticide applications and costs. Water management projects are a part of the Mosquito Control Section's Integrated Pest Management (IPM) program. The IPM program utilizes a combination of mosquito control methods resulting in effective and efficient mosquito control operations.



Saltmarsh killifish are natural predators of mosquito larvae. They are abundant in tidal wetlands, but access to mosquito breeding locations is often restricted.

Each type of mosquito breeding area requires specialized water management techniques. Open Marsh Water Management (OMWM) is the preferred technique in salt marshes and involves selective excavation of ponds and ditches in mosquito breeding areas. Mosquito control is achieved in OMWM treated areas by modifying mosquito